Bioremediation of PAHs: prospecting new mobilizing approaches to improve bioavailability

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Bioavailability is one of the most important factors in determining the success or failure in the bioremediation of soils polluted by hydrophobic organic chemicals (HOCs) like polycyclic aromatic hydrocarbons (PAHs). Current bioremediation technology faces this situation by periodical substrate homogenization and, when it is cost-effective and technically feasible, by the addition of chemical or biological surfactants. We have prospected two new mobilization approaches, one based on chemotactic bacteria and another focused on electrokinetics, to further bioremediation performance.

Chemotaxis. Bacterial chemotaxis enables motile cells to move along chemical gradients and to swim towards optimal places for biodegradation. However, its potentially positive effects on subsurface remediation rely on the efficiency of bacterial movement in porous media, which is often restricted by high deposition rates and adhesion to soil surfaces. In well-controlled column systems, we assessed the influence of the chemoeffectors naphthalene, salicylate, fumarate, and acetate on deposition of chemotactic, naphthalene-degrading *Pseudomonas putida* G7 and its chemotaxis-negative mutant *P. putida* G7.C1 (pHG1000) in selected porous environments (sand, forest soil, and clay aggregates). Our data showed that the presence of the chemoeffectors in the pore water decreased deposition of strain G7 (but not of strain G7.C1) by 50% in sand-filled columns. Similar effects were observed for the other chemoeffectors. Deposition, however, depended on the chemoeffector's chemical structure, its interaction with the column packing material, and concomitantly its pore-water concentration. We suggest that chemotactic sensing, combined with changed swimming modes, is likely to influence the deposition of bacteria in the subsurface, provided that the chemoeffector is dissolved at sufficient concentration in the pore water.

Electroosmosis. The integration of bioremediation and electrokinetics (electrobioremediation) for the treatment of hydrophobic organic soil-contaminants has recently been addressed as a relevant innovative step in soil remediation. However, to our knowledge, there have been limited attempts (documented) to connect these two technologies with remediation of HOCs and, more specifically, PAHs. We employed soils with different texture (clay soil and loamy sand) containing a mixture of PAHs present in creosote, and inoculation with a representative soil bacterium (*Mycobacterium gilvum* VM552) able to degrade fluorene, phenanthrene, fluoranthene, pyrene, anthracene and benzo[a]pyrene. Two different modes of treatment were prospected: 1) inducing in soil the simultaneous occurrence of biodegradation and electroosmosis in the presence of a biodegradable surfactant, and 2) treating sequentially the soils with electrokinetics and bioremediation. Losses of PAH due to biodegradation and electroosmosis (induced by a continuous electric field) were significantly higher than in control cells that contained the surfactant but no biological activity or no current. The method was especially successful with loamy sand. For example, benzo[a]pyrene decreased its concentration in 50 % after 7 days, whereas 22 and 17 % of the compound had disappeared as a result of electrokinetic flushing and bioremediation alone, respectively. The use of periodical changes in polarity and current pulses increased in 16 % the removal of total PAHs and up to 30 % of specific compounds, including benzo[a]pyrene. An electrokinetic pre-treatment was also evaluated as a way to mobilise the less bioaccessible fraction of PAHs. Residual concentrations of total biodegradable PAHs, remaining after bioremediation in soil slurries, were twofold lower in electrokinetically pre-treated soils than in untreated soils.

Keywords PAH; Bioavailability; Chemotaxis, Electrobioremediation